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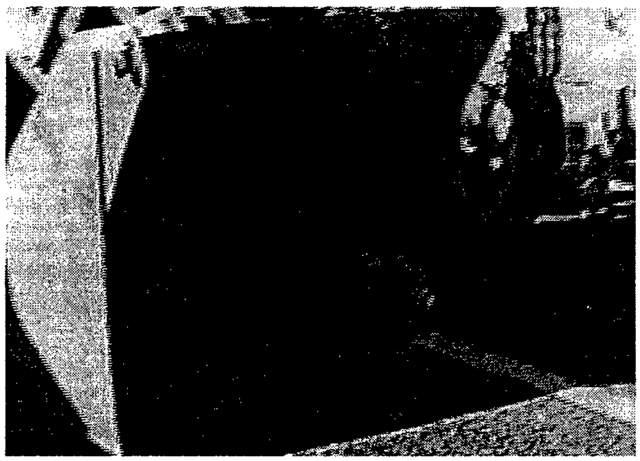

Delamination Surveys and Removal Procedures for Rubberized Asphalt Chip Seal (RACS) Bridge Deck Overlays

Study SD96-19
Final Report

Prepared by
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Mechanical Engineering Department
South Dakota School of Mines and Technology
Rapid City, SD 57701

July, 1998

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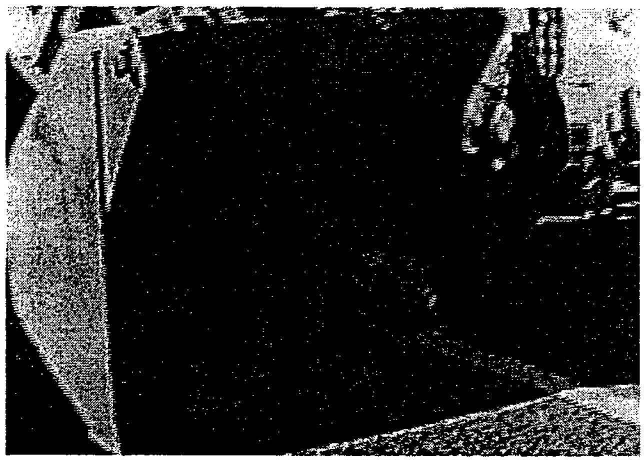

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DISCLAIMER

The contents of this report reflect the views of the authors who are responsible for the facts and accuracy of the data presented herein. The contents do not necessarily reflect the official views or policies of the South Dakota Department of Transportation, the State Transportation Commission, or the Federal Highway Administration. This report does not constitute a standard, specification, or regulation.

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Hal Rumpca	Office of Research	Gerald Menor	Mitchell Region
Dan Johnston	Office of Research	Tom Gilsrud	Bridge Design
Gene Gunsalas	Rapid City Region	Mark Clausen	FHWA
Paul Nelson	Pierre Region		

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16. Abstract

Rubberized Asphalt Chip Seal (RACS) has been used for several decades to protect the bridges in South Dakota. RACS, among other things, prevents South Dakota Department of Transportation (SDDOT) from evaluating the integrity of the bridge decks in an efficient and accurate manner. This study investigated methods to remove the RACS layer from the bridges in South Dakota.

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EXECUTIVE SUMMARY

The South Dakota Department of Transportation has over 470 bridge decks with Rubberized Asphalt Chip Seal (RACS) overlays. A "chain drag" test is often used to determine the condition of the bridge deck and the degree of delamination damage present. The condition of the bridge constitutes a large part of the rating system used to characterize the condition of the decks. This bridge rating system partially determines the amount of bridge replacement funding each state will receive.

A RACS overlay prevents accurate measurements of the condition of the bridge from being obtained. When the results of the chain drag test were compared to those obtained from actual core samples, the results of the two test methods were found to vary significantly.

When bridge repairs or concrete overlays have to be performed, the RACS layer must be removed. This presents a major problem since the current RACS removal attempts have been slow and costly, and may harm the concrete deck surface. Since the RACS prevents accurate delamination survey from being performed, corrective deck treatments may not have been necessary absent RACS removal damage.

Therefore, it is crucial that a feasible technology or procedure for removing the RACS without damaging the underlying decks be developed. A number of other considerations are associated with RACS removal process, such as overall cost, removal rate, and environmental factors. These issues were investigated and are discussed in more detail in the following report.

The procedure followed during the investigation was to first examine numerous options available for RACS removal. These were organized into a "decision matrix" and a formal procedure was followed to extract the most likely candidate methods for futher investigation, namely, scraping, high pressure washing, and melting.

These three candidate methods were then examined more closely in the laboratory in an effort to single out one prototype method for full-scale field testing. Lab tests were conducted on RACS-covered bridge deck samples supplied by SDDOT. After considering a number of factors, scraping with heating was deemed to be the method with most potential for success upon scale-up.

A full-scale field test was conducted on an I-90 bridge deck. A propane heater towed by a truck was used to heat the RACS. Both a front-end loader and a grader were used to scrape the bridge deck. The trial successfully met the project specifications, and the report concludes with a recommended implementation procedure, which is reproduced here for convenience:

- Arrange the removal equipment such that the heater is leading the scraper and/or bucket loader.
- Start by checking the temperature of the deck using an infrared pyrometer or other method.
- If the RACS is below a temperature between 52 – 63 degrees C (125 – 140 degrees F), activate the heater (e.g., light all propane burners).
- Allow the heater to heat the RACS and start pulling the heater over the surface very slowly.
- Using an infrared pyrometer or other method, check that the RACS is at a temperature between 52 – 63 degrees C (125 – 140 degrees F). If it is not at the proper temperature, slow the truck and continue checking the temperature until the RACS is ready to be removed.
- When the RACS reaches becomes hot, it becomes very sticky and will bond to the scraping bit. It is therefore necessary to lubricate the blade to prevent the RACS from sticking. Liquid Wrench™ or another non-flammable lubricant should work. The blade may have to be lubricated several times per bridge deck.
- Using the proper scraping angle (nominally 60° – 70°), down pressure (as much as possible without damaging the bridge deck), and speed (as required to keep the RACS at the desired temperature), scrape off the RACS. (To scrape the RACS at the proper temperature, it may be necessary to keep the front-end loader close behind the heater.)
- Once the loader has completed its pass over the deck, the removed RACS may be placed in a dump truck for disposal.

PROBLEM DESCRIPTON

The South Dakota Department of Transportation has over 470 bridge decks with Rubberized Asphalt Chip Seal (RACS) overlays. A "chain drag" test is often used to determine the condition of the bridge deck and the degree of delamination damage. The condition of the bridge constitutes a large part of the rating system used to characterize the condition of the decks. This bridge rating system partially determines the amount of bridge replacement funding each state will receive.

A RACS overlay prevents accurate measurements of the condition of the bridge from being obtained. When the results of the chain drag test were compared to those obtained from actual core samples, the results of the two test methods were found to vary significantly.

When bridge repairs or concrete overlays have to be performed, the RACS layer must be removed. This presents a major problem since the current RACS removal attempts have been slow and costly, and may harm the concrete deck surface. Since the RACS prevents accurate delamination survey from being performed, corrective deck treatments may not have been necessary absent RACS removal damage.

Therefore, it is crucial that a feasible technology or procedure for removing the RACS without damaging the underlying decks be developed. A number of other considerations are associated with RACS removal process, such as overall cost, removal rate and environmental factors. These issues are discussed in more detail in the following sections.

OBJECTIVES

The goal of the SDSM&T design team was to evaluate technologies or procedures for removal of RACS from bridge decks, and develop and demonstrate a prototype device and/or procedure for RACS removal.

This report will discuss the development of the lab-scale prototype used to determine the favorable operating range, the required operating parameters, and the optimum materials. This report will address the following:

- Purpose of making lab-scale prototype

- Process of making a lab-scale prototype
- Testing of the lab-scale prototype
- Development of the full-scale prototype
- Testing and evaluation of the full-scale prototype

Main areas of considerations to be discussed in this report are:

Planning and Organization This section describes the project's constraints, organization, and the planning process.

Preliminary Testing This section describes the brainstorming and decision matrix process used to identify possible removal procedures.

Prototype Design This section describes the process of creating different ideas for the lab-scale prototype.

Prototype Testing This section describes the different tests that were performed on the lab-scale prototype, and the observations that were made.

Full-scale Prototype Design and Testing: This section describes the full-scale prototype design and testing.

PLANNING AND ORGANIZATION

PROJECT SPECIFICATION

The communication between the design team and the SDDOT was vital to the success of this project. The design team and the SDDOT cooperated in the development of the specification needed to fulfill the project requirements. The specifications are listed in Table 1 below.

Table 1. Project Specifications.

- The device must be able to remove RACS at a thickness of up to 2.54 cm (1 inch).
- The prototype removal rate should be no less than 0.6-0.7 m^2/min (6-8 ft^2/min).
- Bare concrete need not be exposed, but no more than 0.76-1.5 mm (0.030-0.060 in) of RACS should remain.
- Removed RACS must be collected, or be readily collectable.
- Device and process must be safe, repeatable, reliable and suitable for use in remote locations
- The development budget is $5000.
- Solvents that are not biodegradable should not be used.
- Environmental impact of RACS removal must be minimized.
- Bridge deck must not be damaged by mechanical, chemical, or other means.
- Cost and skill level associated with operation of the device and process must be minimized.
- The operation cost must be minimized and not exceed $2.39/$m^2$ ($2/$yd^2$).

ORGANIZATION

A design team was created that incorporated chemical, metallurgical, and mechanical engineering students. Three faculty advisers were also contributed to the project. The organization of the design team is shown below:

Project Leader

Dr. Christopher Jenkins
Mechanical Engineering

Technical Advisers

Dr. Jon Kellar
Metallurgical Engineering

Dr. Rob Winter
Chemical Engineering

Team Leader

Atle Lernes
Mechanical Engineering

Team Members

Alan Freeland
Mechanical Engineering

Annie Thompson
Metallurgical Engineering

Darren Hepper
Chemical Engineering

Beau Brewer
Mechanical Engineering

PRELIMINARY TESTING

INTRODUCTION

After extensive research, very little information on RACS removal was found. Therefore preliminary removal methods had to be developed before a prototype could be designed. This section will discuss the brainstorming and testing activities needed to identify a viable RACS removal process.

CONCEPTUALIZATION

The design team identified possible methods that could be used to remove the RACS. These methods were the basis for the development of the preliminary testing. A decision matrix was used to evaluate the various removal methods. In the decision matrix, each specification was weighted on a 0-10 scale based on the relative importance of that particular specification. (The weight values are necessarily subjective, but represent a composite of estimates by project team members, faculty advisors, and SDDOT personnel.) Each method was then evaluated by the members of the design team on a scale of 1-3 based on how well each method fulfilled the specifications. A rating of three was used to indicate that the particular method fulfilled the specification well while a one rating indicated poor fulfillment. The rating for each constraint was then multiplied by its weight, and then the total score for each method was calculated. The scores from each design team member were summarized, and the highest-ranking methods were considered for further development.

Furthermore, the same decision matrix was given to SDDOT for additional input. The totals from each process were determined by multiplying the weight by the rank, and then adding these scores. The summary decision matrix is shown in Table 2 below.

Table 2. SDDOT Decision Matrix.

Constraints	Weight	Grinding	Melting	Cutting	Blasting	Scraping	Dissolving	Debonding
Minimum removal rate 0.6-0.7 m^2/min.	6	1	3	2	3	3	3	3
Remove RACS at various thickness up to 2.54 cm thick	10	1	3	2	2	3	2	3
0.76-1.5 mm remaining RACS layer	10	1	3	1	3	2	3	3
Removed RACS must be collectable or collected	8	1	1	2	2	3	1	3
Repeatability	10	1	3	2	2	3	3	3
Reliability	7	1	3	2	2	2	3	2
Safety	10	1	1	2	2	3	2	2
Remote operation	7	2	2	2	2	2	3	3
Environmental impact must be a minimum	10	1	1	2	3	3	1	2
Bridge deck must not be damaged	10	1	1	1	3	2	2	2
Maintainability	7	1	2	1	2	2	3	3
Operation cost:	6	1	1	2	2	2	2	2
Design temperature: 16-49 degrees C ambient air	6	2	3	2	3	2	2	2
Operation skills requirement	5	1	2	1	2	2	2	2
Operation time should be maximum 8 hours	10	3	3	3	3	3	2	1
		155	259	222	296	**308**	273	292

Based on the results from the decision matrix, the design team decided that the scraping, water blasting, and heating methods were potentially the most effective removal methods for further investigation. (Although "debonding" and "dissolving" rated higher than "melting", resource and time limitations precluded further investigations of these methods.)

TESTING

At the request of the design team, SDDOT supplied four concrete slabs with RACS overlays. A testing program was developed based on the result from the decision matrix, discussed in the previous section. The main purpose of the RACS removal testing was to determine the following:

- Ideal ambient and deck temperature ranges for the removal process.
- Most effective removal method.
- Force necessary to remove the RACS.
- Removal speed
- Best combination of removal methods.
- Justification of further development of a specific lab-scale prototype.

Solvents

The use of solvents was considered for two aspects of this project: removal of any RACS remaining after the heating/scraping procedure, and lubrication or cleaning of the scraping surface. As previously noted in the constraints section, any solvents used must be biodegradable, and no more than 0.76 - 1.5 mm (0.030 - 0.060 inch) of RACS should remain after removal.

In compliance with the biodegradability constraint, only those solvents which are not regulated under SARA Title III sections 311 and 312, and are not considered hazardous or restricted by EPA RCRA were considered. During the initial solvent testing, it became apparent the biodegradability of the solvent is irrelevant since the RACS renders the solution non-biodegradable once dissolved. However, the biodegradability constraint was not discarded since biodegradable solvents are generally less flammable and have higher flash points than non-biodegradable solvents.

After extensive testing, ATR Hi-Flash Asphalt Solvent was found to be most appropriate for this application. ATR Hi-Flash contains a blend of highly-refined terpene hydrocarbons, and is specially formulated for the removal of asphalt from field equipment.

Since the heating/scraping process removes sufficient RACS to fulfill the second constraint mentioned above, the solvent need not be applied directly to the bridge decks. The solvent need only be used to clean the scraping surface and any other equipment to which the softened RACS becomes bonded.

Preliminary Test Methods

The tests were done on 1.2 m by 1.2 m (4' by 4') slabs of concrete with the RACS on the surface. The slabs were taken from a bridge deck with RACS that was approximately ten years old. The first test method evaluated was water blasting. For this method, several nozzles at different sizes were used at various application angles to achieve the maximum RACS removal. Figure 1 shows a typical water blasting trial. The result of this trial are shown in Figure 2.

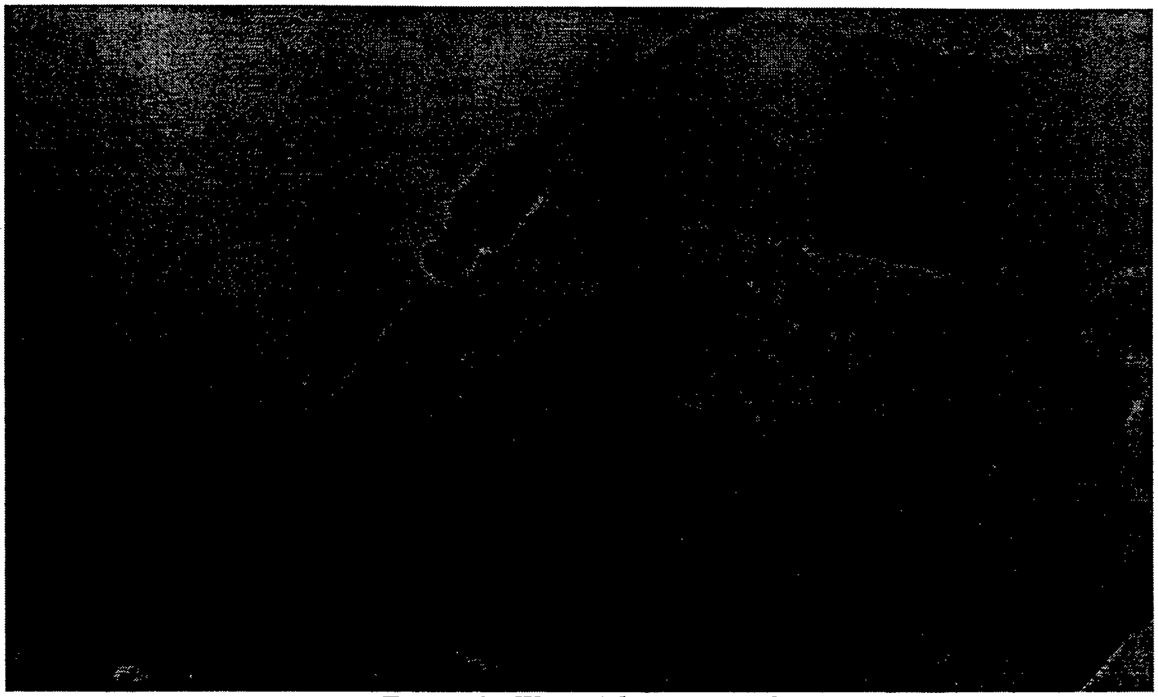

Figure 1. Water Blasting Trial.

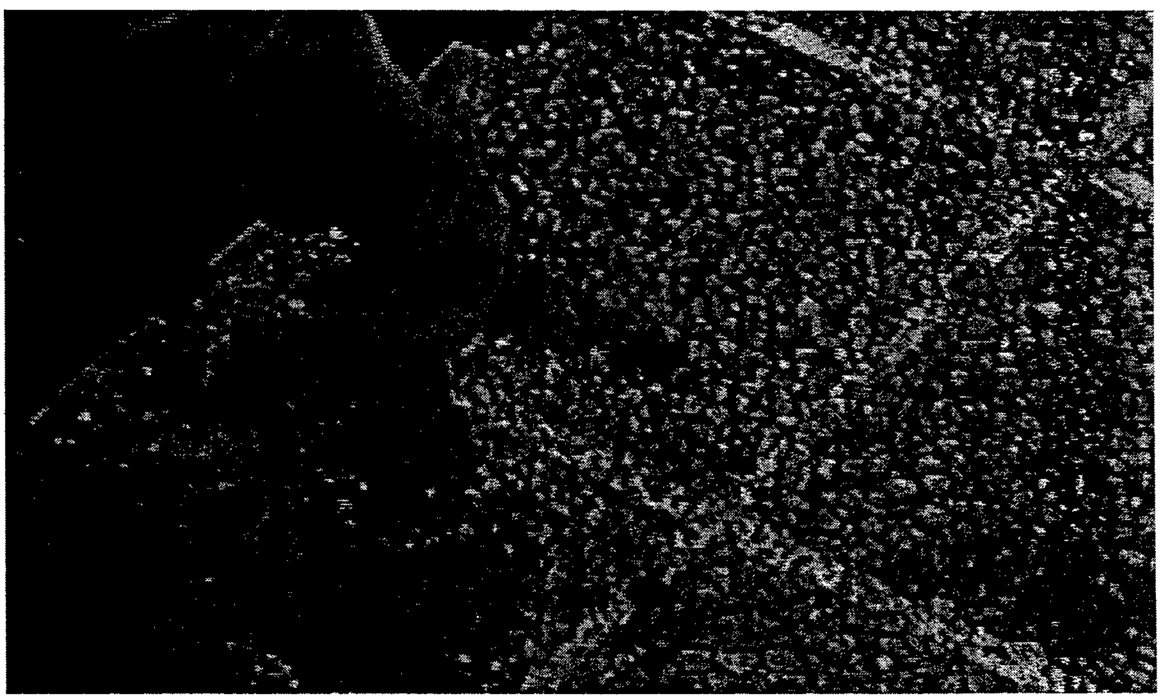

Figure 2. Water Blasting Result.

The next method examined was scraping. For this method, the RACS was heated to various temperatures with an infrared light bulb for five minutes and removed with a simple scraper. The temperature of the RACS was measured using a digital thermometer. The inclination angle of the blade was also varied to determine the optimum scraping angle. The RACS were easily removed with this method. An example of the scraping method is shown in Figure 3. The results of this trial are shown in Figure 4.

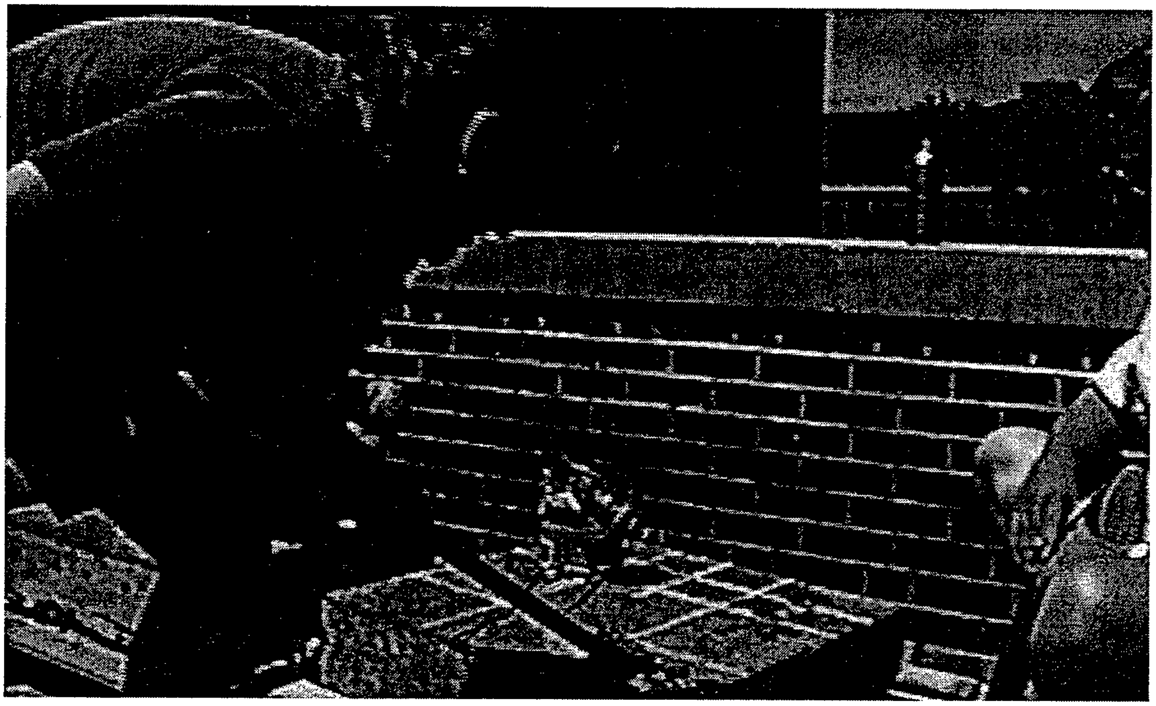

Figure 3. Scraping Method.

Figure 4. Scraping Method Result

The third method evaluated in the preliminary testing was the use of solvents. The solvent was applied directly to the RACS layer. This process is shown in Figure 5.

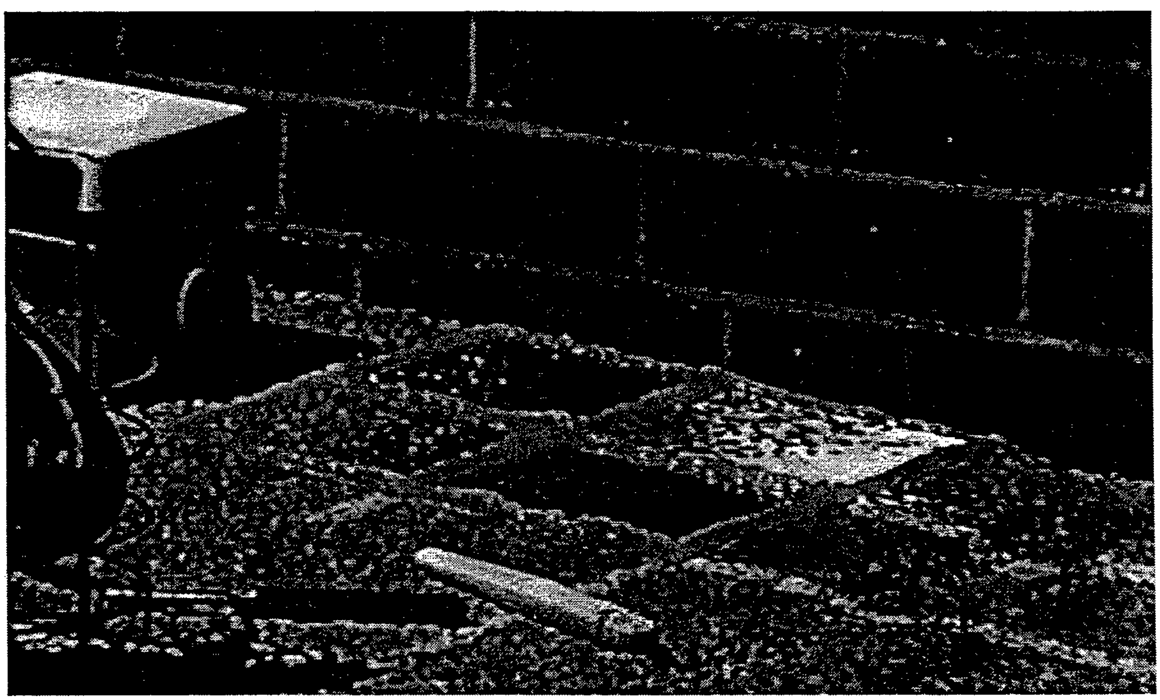

Figure 5. Preliminary Solvent Application.

During the solvent tests, the solvent proved virtually ineffective when applied directly to the RACS. However, the solvent successfully removed the residual RACS remaining after the heating-scraping process.

The results from the different solvent tests are tabulated in Table 3 below.

Table 3. Preliminary Solvent Test Results

No	N	DH	SH	SA	Solvent	AT [C]	DT [C]	Humidity	Force [N]	EOR	RTL	RT	Speed	CO
1		x		30	Tarbuster	22	49	57%	-	Good	100%	100%	Quick	Good
2			x	30		22	43	57%	-	Hard	0%	0%	Very slow	Poor
3		x	x	30	#1	22	60	57%	-	Good	100%	100%	Quick	Good
4	x	x		30	ATR	18	52	63%	-	Good	100%	100%	Quick	Good
5	x	x		30	ATR	20	60	63%	-	Good	100%	100%	Quick	Good
6	x	x		45	ATR-C	24	55	35%	334	Good	100%	70%	Quick	Good
7	x	x		30	ATR Hi	24	131	35%	267	Good	100%	100%	Quick	Good

Abbreviations:

EOR:	Ease of removal	CO:	Collectability
N	Notch (pilot to begin scraping)	RTL	Remaining top layer
DH:	Deck heated	RT:	Remaining rubberized asphalt
SH	Scraper heated	DT:	RACS temperature [° C]
SA:	Scraping angle (degrees)	AT	Ambient temperature [° C]

TEST ANALYSIS

The preliminary testing provided the necessary information for the development of the lab-scale prototype. Based on these test results, the following observations were noted.

1. The water blasting method proved to be ineffective due the slow removal rate, and the difficulties associated with the collection of the RACS.
2. The optimal RACS scraping temperature was between 46 to 57 °C (115 to 135 °F).
3. The thickness of the RACS remaining after the heating-scraping process was largest when the deck temperature was high.
4. The force required to remove the RACS decreased as the scraped inclination angle decreased.
5. The rubberized asphalt (RACS-solvent) solution must be collected due to the impact on the environment.
6. The rubberized asphalt stuck on the scraper blade, however, using a solvent as lubrication prevented this occurrence.

The lab-scale prototype was designed based on the results of the preliminary testing. In order evaluate the preliminary testing results, another decision matrix was used to determine the most effective removal method. This matrix is shown in Table 4.

Table 4. Prototype Decision Matrix.

Constraints	Weight	Heating Scraping Solvent	Heating Blasting	Heating Scraping Blasting
Minimum removal rate 0.6-0.7 m^2/min.	6	3	3	3
Remove RACS at various thickness up to 2.54 cm thick	10	3	3	3
0.76-1.5 mm remaining RACS layer	10	3	3	2
Removed RACS must be collectable or collected	8	3	1	3
Repeatability	10	3	3	3
Reliability	7	2	3	2
Safety	10	3	1.7	2
Remote operation	7	3	3	3
Environmental impact must be a minimum	10	2	2.3	2
Bridge deck must not be damaged	10	3	2.3	2
Maintainability	7	3	3	3
Operation cost:	6	1.3	2	2
Design temperature: 16-49 degrees C ambient air	6	0	0	0
Operation skills requirement	5	2.3	3	3
Operation time should be maximum 8 hours	10	3	3	3
		317.3	299	295

Based on the decision matrix, the design team reached the conclusion that the heating- scraping-solvent method was the best method for removing the RACS layer.

SUMMARY

Based upon the preliminary test results, the best RACS removal method in the lab is to first heat the RACS to a temperature between 46-54 °C (115-130 °F), then scrape the RACS, and apply ATR Hi-Flash solvent to remove the remaining RACS layer. This procedure (heating and scraping) should be performed when the bridge deck temperature is below 16 °C (60 °F) to minimize the thickness of the residual RACS. (The 16 °C temperature need not be maintained during solvent application.) As indicated in the Material Safety Data Sheet (Appendix A), ATR Hi-Flash solvent "...contains highly refined terpene hydrocarbons, which are not considered hazardous or restricted by EPA RCRA; hence, the environmental impact of the solvent clean up procedure is expected to be minimal if ordinary and reasonable care is taken. However, such a clean up was never attempted in this project on an actual bridge deck.

LAB-SCALE PROTOTYPE DESIGN

INTRODUCTION

Based on the testing results, a lab-scale prototype was designed. The main goal of the prototype was to determine the best scraping angle, temperature, average force and feed rate for the heating and scraping process. A secondary goal was to test different blade materials and different lubrications to prevent RACS from sticking to the blade. The following sections will discuss the preliminary and detail designs of the lab-scale prototype.

PRELIMINARY DESIGN

In order to design a lab-scale prototype that would meet the objectives, we considered several design concepts for the prototype. The final prototype design was chosen based on its ability to fulfill the testing requirements. The scraping angle could be adjusted from 5-90 degrees, the average force could be measured through a load cell, and different blade materials and lubrications could be tested. Since a constant force was used, the feed rate could be measured for every configuration.

The basic principle of this design involved a pulley system which pulled an apparatus over the RACS test slab. The apparatus consisted of a trolley to which a scraping blade was attached, as shown in Figure 6. The blade was mounted on a bracket that had two milled tracks which allowed the blade to move vertically so that the depth of the scraping could be varied. By moving the trolley in the tracks, the vertical component of the reactive force from the blade was compensated for. The function of the slot was to adjust the vertical position of the blade and to hold the blade in position. The lab-scale prototype design was made as simple as possible, and yet it still fulfilled the objectives for which it was designed. The lab-scale prototype is shown in Figure 6.

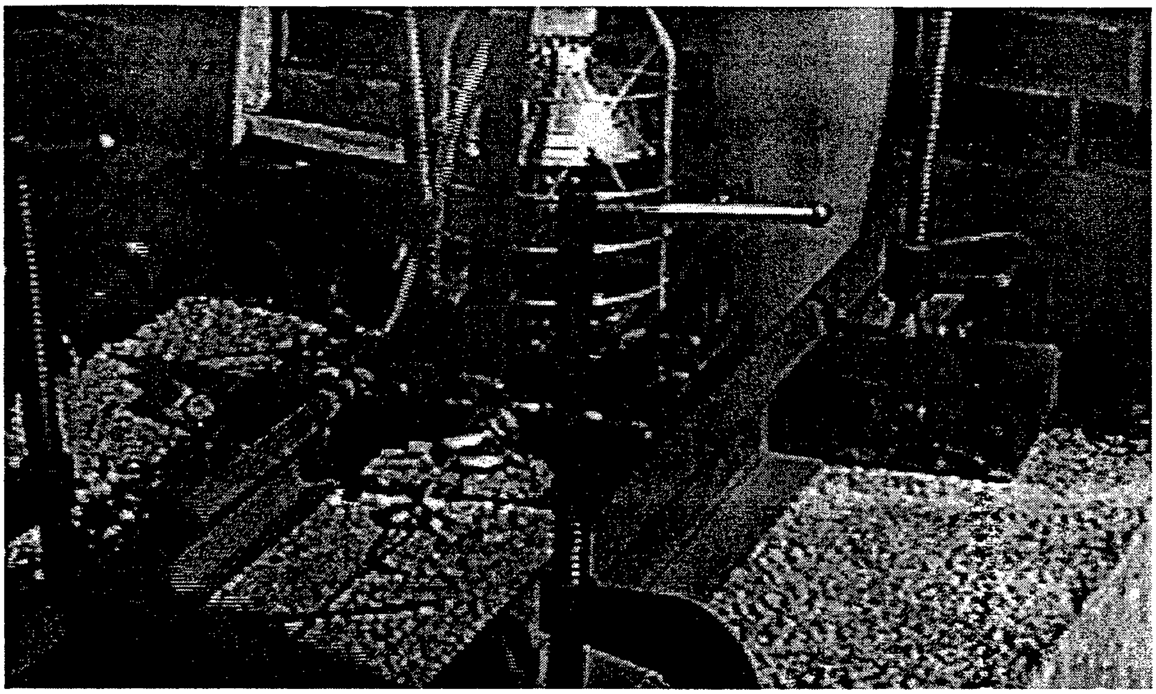

Figure 6. Lab-scale Prototype

The trolley was pulled down its tracks using a gravity loading system to maintain a constant force. The RACS was heated using two infrared heating lamps mounted on the trolley. Before the load was applied, the RACS was preheated using the heating lamps. Once the proper temperature was obtained, the load was applied, and the trolley was allowed to travel the length of the sample slab. The temperature was controlled by varying the distance between the heating lamps and the RACS surface. The force was varied by adding or removing weight from the gravity loading apparatus.

LAB-SCALE PROTOTYPE TESTING

INTRODUCTION

In order to further evaluate the performance of the lab-scale prototype, three major types of tests were performed: force, scraping angle, and temperature effects. The purpose of these tests was to confirm the validity of the preliminary test results.

PROTOTYPE TESTING

Force Effect Test

To determine the effect of increasing feed rates (~ 5mm/s – 13 mm/s typical range) on the remaining rubberized asphalt layer, a force effect test was performed. The RACS was scraped using several values of forces. For each of these experiments, the horizontal force applied to the prototype was constant. Loads of 320 and 472 N (72 and 106 lb) were used. The results of the force effect tests indicated that by increasing the force applied, the thickness of the residual RACS was minimized. Also, by increasing the load, faster feed rates were obtained.

Scraping Angle Effect Test

The effect of varying the scraping angle was investigated by scraping the test slab at different blade angles (approximately 30 and 45 degrees measured relative to the RACS surface). This test indicated that a smaller angle yielded a cleaner surface than did a larger scraping angle.

Temperature Effect Test

In the preliminary testing, the thickness of the residual RACS was found to be strongly dependent upon the temperature of the RACS. To confirm this observation, a temperature effect test was performed. The RACS was heated to temperatures ranging from 46 – 66 °C (115-150 °F). It was found that the removal rate increased with the increase of RACS temperature within this range. However, above 66 °C (150 °F) removal of the residual RACS layer deteriorated due to its increased molten state. The *initial* concrete and RACS temperature had only slightly affected the residual RACS layer.

It was also observed that the down pressure on the blade was the major factor that determined the thickness of the residual RACS (within the temperature range specified above). Also, an inverse relationship was observed between the feed rate and the thickness of the remaining layer. With sufficient down pressure, the remaining RACS layer was within the required constraint of 0.76 – 1.5 mm (0.03-0.06 in).

SUMMARY

The major observations made during the testing of the prototype were:

1. The initial temperature of the concrete and the RACS do not strongly influence the thickness of the remaining RACS.
2. The down-pressure on the blade influenced the thickness of the remaining RACS. With the limited scraping force available, the smaller scraping angle gave better removal results.
3. With an increase in the feed rate (~ 5mm/s – 13 mm/s typical range), the thickness of the remaining RACS decreases.
4. The heating and scraping method was found to be an effective method for RACS removal. Scaled to the full-scale prototype, these results meet the project specifications.

FULL-SCALE PROTOTYPE TESTING

Full-scale testing was performed August 26, 1997, on a small bridge located at mile marker 52, approximately 5 miles west of Rapid City on Interstate 90. The heating of the RACS was done with an existing propane heater owned by the Department of Transportation. The heater was pulled over the RACS surface by a pickup truck to obtain the proper feed rate needed to heat the RACS to the desired temperature. (All equipment used was furnished by SDDOT.)

The field testing began by measuring the temperature of the RACS. The testing was begun at 7:00 AM, and the temperature of the surface was 18 °C (64 °F). Next, the RACS was heated by pulling the propane heater across the RACS at a rate such that the RACS was heated to approximately 52 °C (125 °F). Figure 7 illustrates this heating process.

Figure 7. RACS Heating Process.

The first RACS removal method investigated involved the use of a grader to remove the heated RACS. This method effectively removed the RACS; however a front-end loader was necessary to remove the windrow created by the grader. The use of a grader for RACS removal is shown in Figure 8.

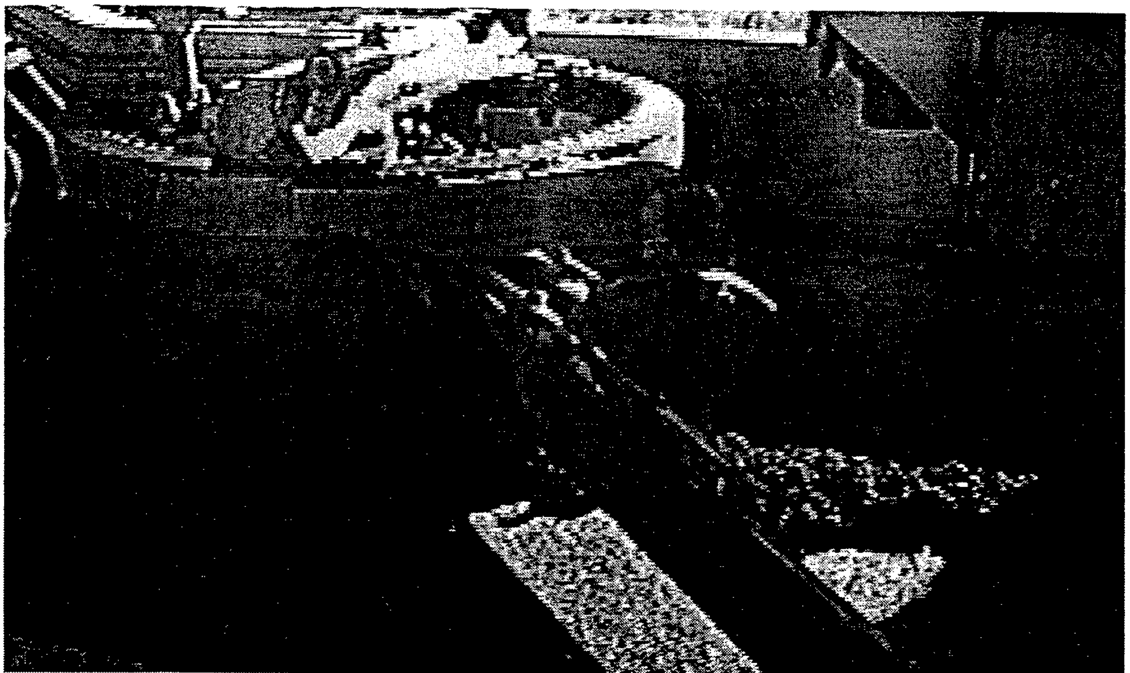

Figure 8. Use of Grader for RACS Removal.

The grader was quite effective in the RACS removal, as shown in Figure 9. However, the process seemed quite inefficient since the RACS windrow had to be collected with a front-end loader after each pass as shown in Figure 10.

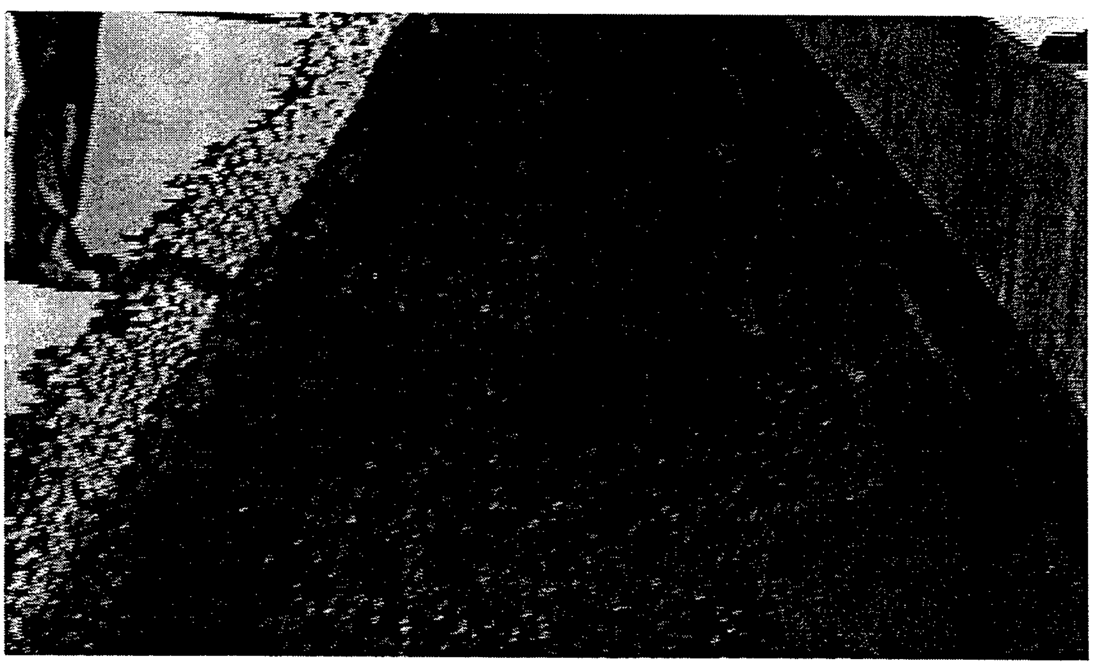

Figure 9. Results of Grader Test.

Figure 10. Use of Front-End Loader for RACS Collection.

For the final test, the front-end loader was used to remove the RACS. This process is shown in Figure 11.

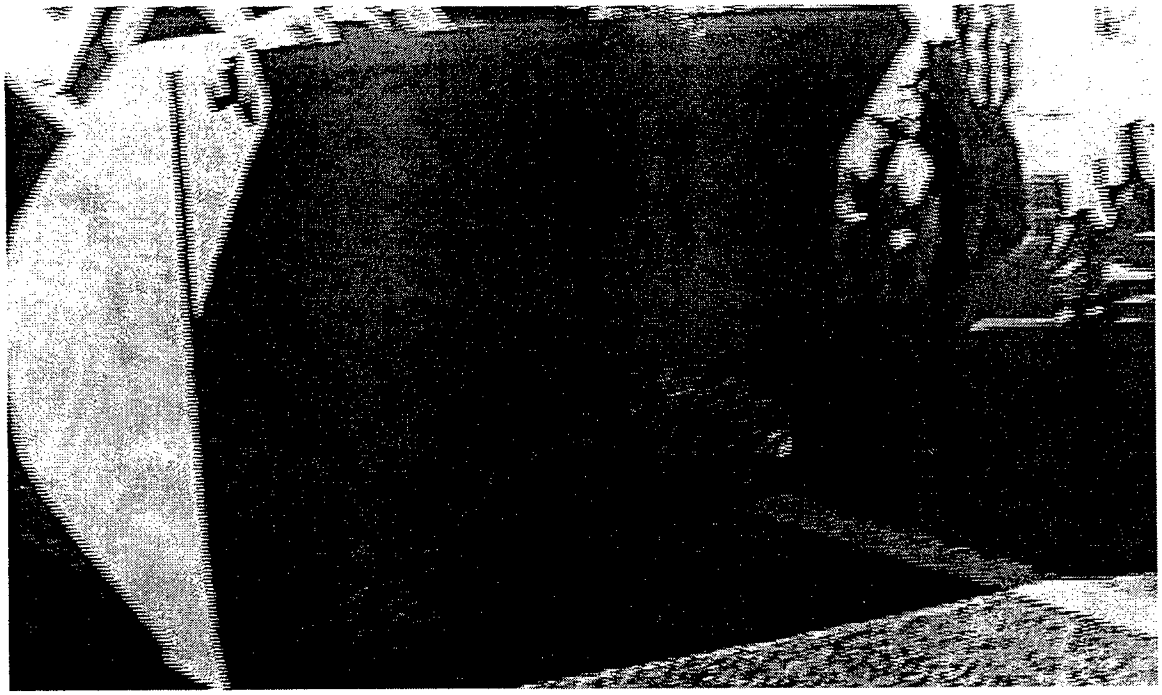

Figure 11. Use of Front-End Loader for RACS Removal.

The results of the RACS removal using the front-end loader are shown in Figure 12.

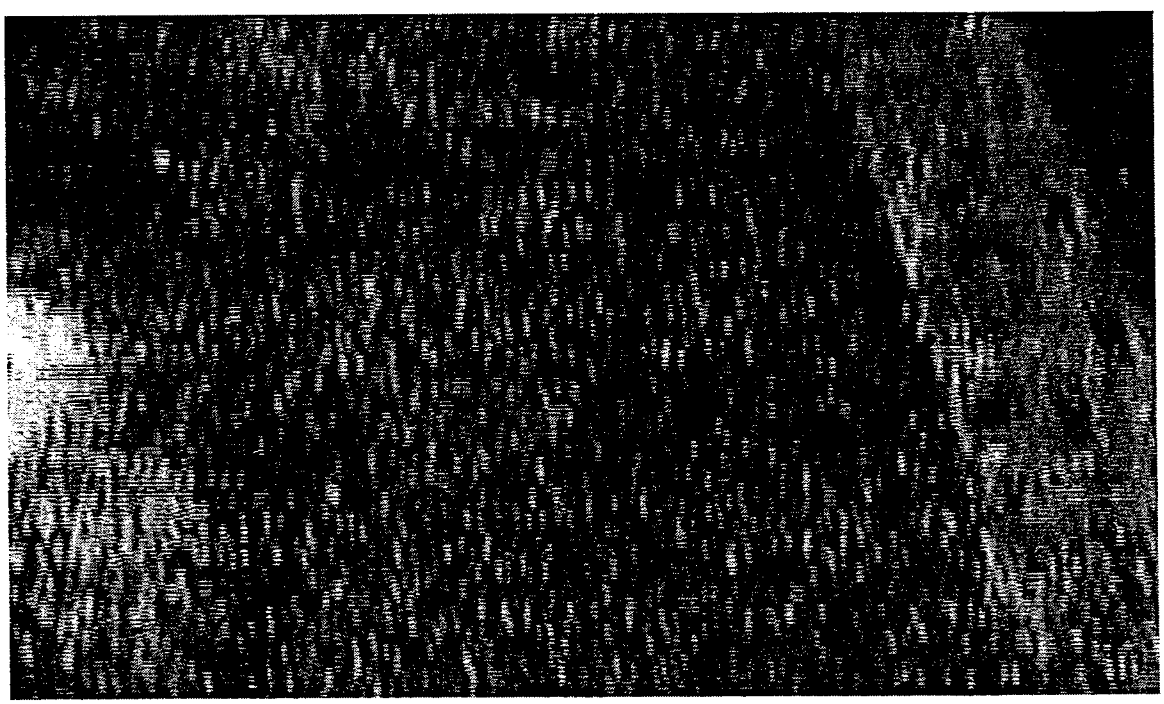

Figure 12. Results of RACS Removal Using Front-End Loader.

As shown in Figure 12, the front-end loader removed the RACS quite effectively and also allowed for easy collection. The result of the full-scale prototype field test was that the original project criteria were met.

As might be expected, considerable differences existed between the lab-scale and full-scale field tests. The size of the blade and down-pressure available were considerably larger in the field tests than in the lab; this influenced the scraping angle used in the field relative to in the lab. The field environment itself is quite different: The thermal mass of the bridge deck, the solar heating variations, and the wind all play a more significant role in the field tests than in the lab.

Although high-pressure washing was investigated in the lab, it was not attempted in the field tests due to the poor lab results for this method. Nor was any attempt made to remove the remaining rubberized asphalt layer; this was consistent with our original project specification to leave no more than 0.76 – 1.5 mm remaining of the layer (which was met in the field tests). (In this condition, skid tests should be considered to assess the safety for vehicle traffic in wet conditions.)

CONCLUSION

Through the experiments conducted at SDSM&T, it was found that the best temperature range for the removal of the RACS is when the RACS is between 52-63 °C (125-145 °F). Since the thickness of the residual RACS layer is strongly dependent on temperature, it is essential the temperature of the RACS be accurately measured. It is suggested that the surface temperature be monitored by a portable infrared pyrometer. This infrared pyrometer will allow the technician to walk behind the heater and take instantaneous temperatures of the RACS surface. Another way to check the approximate temperature of the surface is by inspection. When the RACS is heated, its surface appearance changes. As it is heated to the desired temperature, the surface starts to display small glossy black spots. The more spots, the hotter the surface temperature. After some experience with the pyrometer and inspection, a technician will be able to tell from the glossy black spots when the RACS is ready to be scraped.

It is suggested that the scraping of the RACS be executed with the assistance of a front-end loader. It has been found that the loader is the most efficient scraper because as the scraping is conducted, the RACS is also collected in the bucket. One important aspect of the front-end loader is the bit of the bucket. For the best removal, the bit of the bucket must be quite sharp. If a dull bit is used the remaining rubberized asphalt layer will increase significantly. Also the angle that the bit scrapes against the surface is important. It is suggested that the operator of the loader keeps the angle approximately 60 to 70°, from the horizontal, as the scraping is conducted. Another very important aspect of the scraping is the amount of "down force" the operator uses. It is strongly suggested that the operator use as much "down force" as the loader will permit without damaging the underlying bridge deck. The remaining rubberized asphalt layer is minimized by using more "down force". Finally the operator must also be careful not to scrape the surface too quickly. A "chattering" of the bucket occurs if scraped to fast which increases the thickness of the residual RACS.

Questions naturally arise as to the impacts of summer day time temperatures on the removal process. As noted previously, the residual layer thickness is reduced as the concrete bridge deck temperature is lowered. Hence, this would suggest the ideal weather for RACS removal would be a warm to hot calm day following a cool night. However, due to lack of funds, no formal study of the effects of solar heating days or diurnal temperatures on the RACS removal process was able to be conducuted.

IMPLEMENTATION RECOMMENDATIONS

As in many construction processes, hard and fast rules are difficult to prescribe, due to the many variable encountered in the field. However, the following list provides a baseline set of instructions, which can be modified as conditions demand and experience allows.

- Arrange the removal equipment such that the heater is leading the scraper and/or bucket loader.
- Start by checking the temperature of the deck using an infrared pyrometer or other method.
- If the RACS is below a temperature between 52 – 63 degrees C (125 – 140 degrees F), activate the heater (e.g., light all propane burners).
- Allow the heater to heat the RACS and start pulling the heater over the surface very slowly.
- Using an infrared pyrometer or other method, check that the RACS is at a temperature between 52 – 63 degrees C (125 – 140 degrees F). If it is not at the proper temperature, slow the truck and continue checking the temperature until the RACS is ready to be removed.
- When the RACS reaches becomes hot, it becomes very sticky and will bond to the scraping bit. It is therefore necessary to lubricate the blade to prevent the RACS from sticking. Liquid Wrench™ or another non-flammable lubricant should work. The blade may have to be lubricated several times per bridge deck.
- Using the proper scraping angle (nominally 60° – 70°), down pressure (as much as possible without damaging the bridge deck), and speed (as required to keep the RACS at the desired temperature), scrape off the RACS. (To scrape the RACS at the proper temperature, it may be necessary to keep the front-end loader close behind the heater.)
- Once the loader has completed its pass over the deck, the removed RACS may be placed in a dump truck for disposal.

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